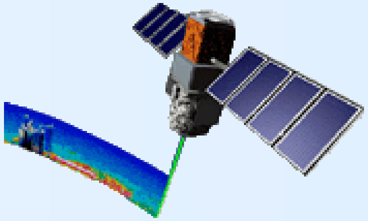
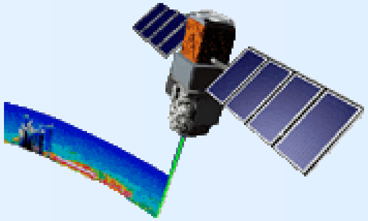
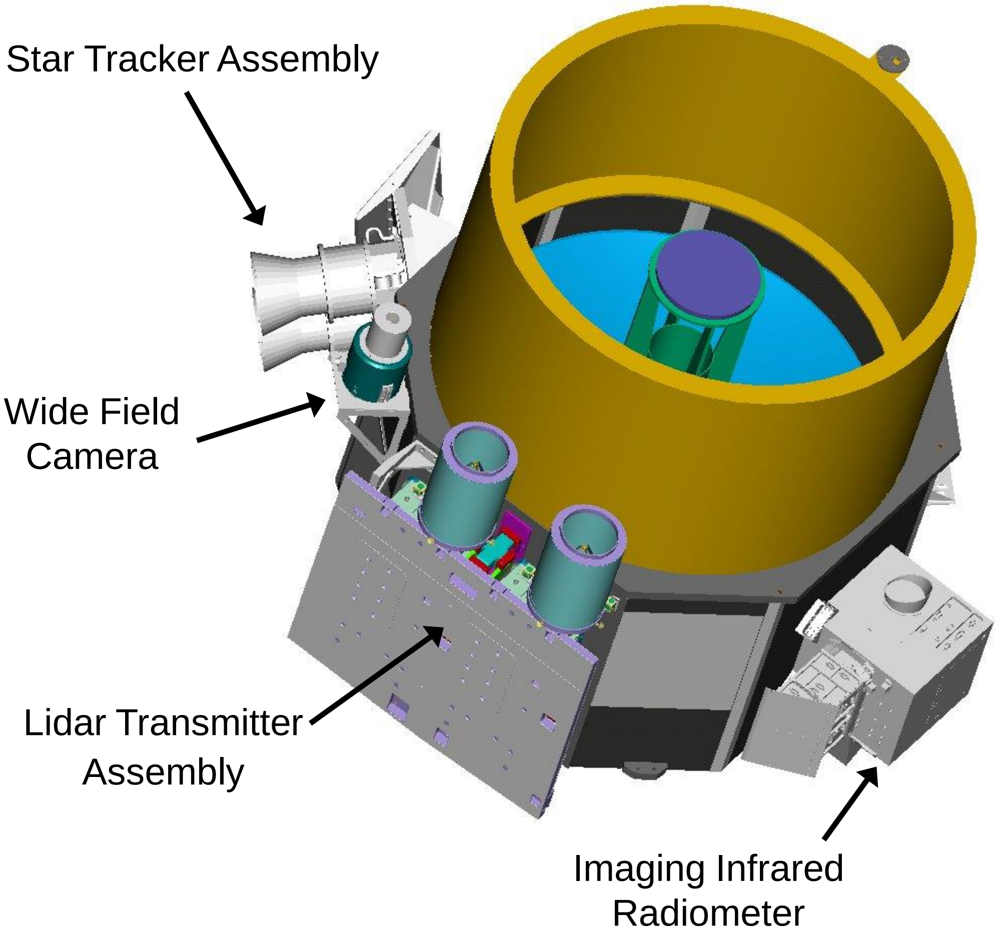
CALIPSO Overview
Presented by Jim Yoe



Status –
D. Winker
Potential Applications –
D. Emmitt, C. Barnet, R.Hoff, J. Yoe

CALIPSO





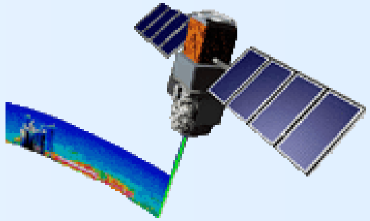
- **Three co-aligned instruments:**
  - **CALIOP**
    (3-channel lidar)
    – 532 nm ||
    – 532 nm ⊥
    – 1064 nm

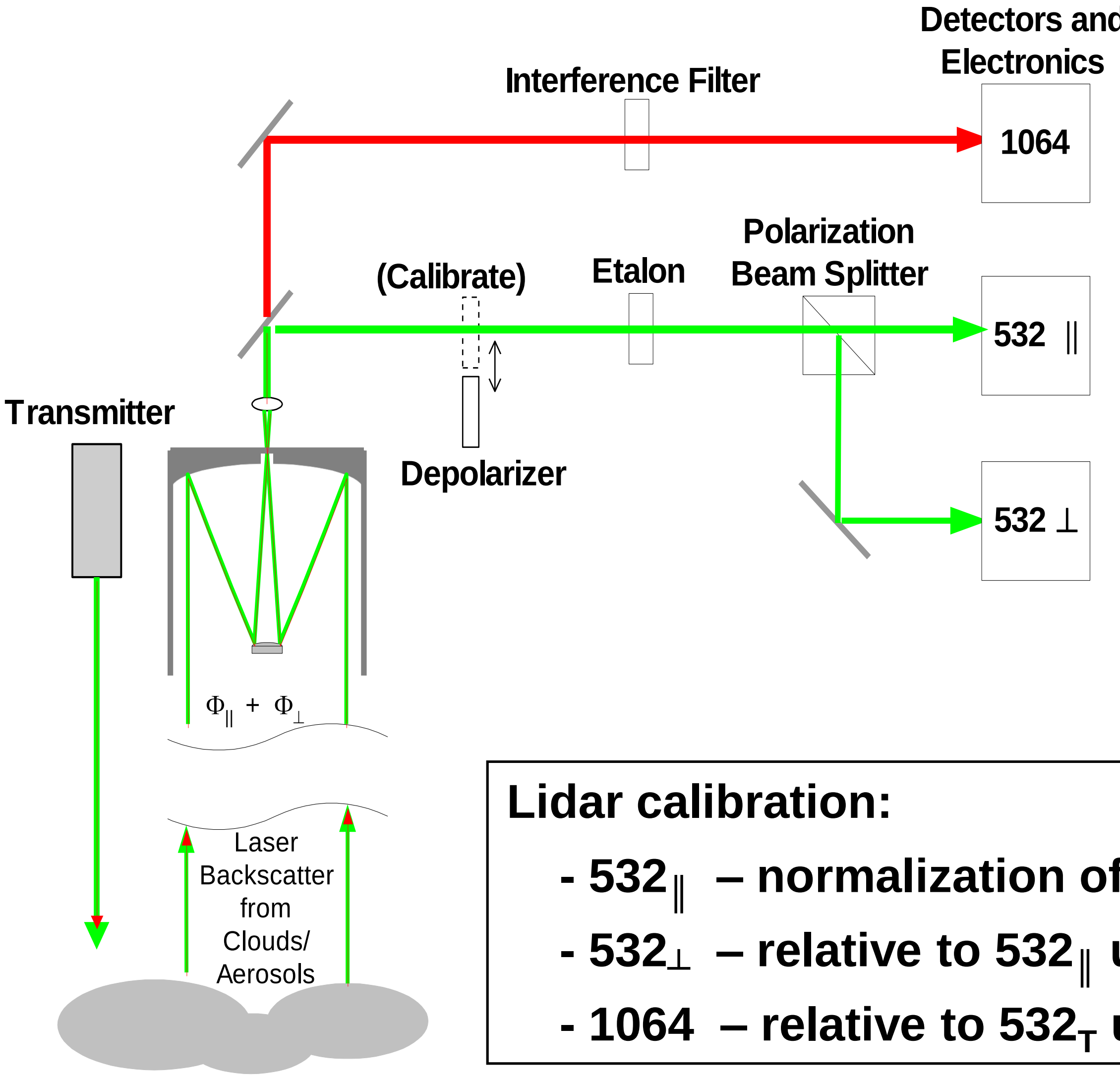
    Aerosol and cloud
    - Layer heights
    - β and σ profiles
    Cloud ice/water phase, IWC

– **Imaging IR radiometer**
– **Wide-Field Camera**

Cloud emissivity
Ice particle size

Lidar Block Diagram





Features:

Analog detection

- 532 nm: PMT's
- 1064 nm: APD

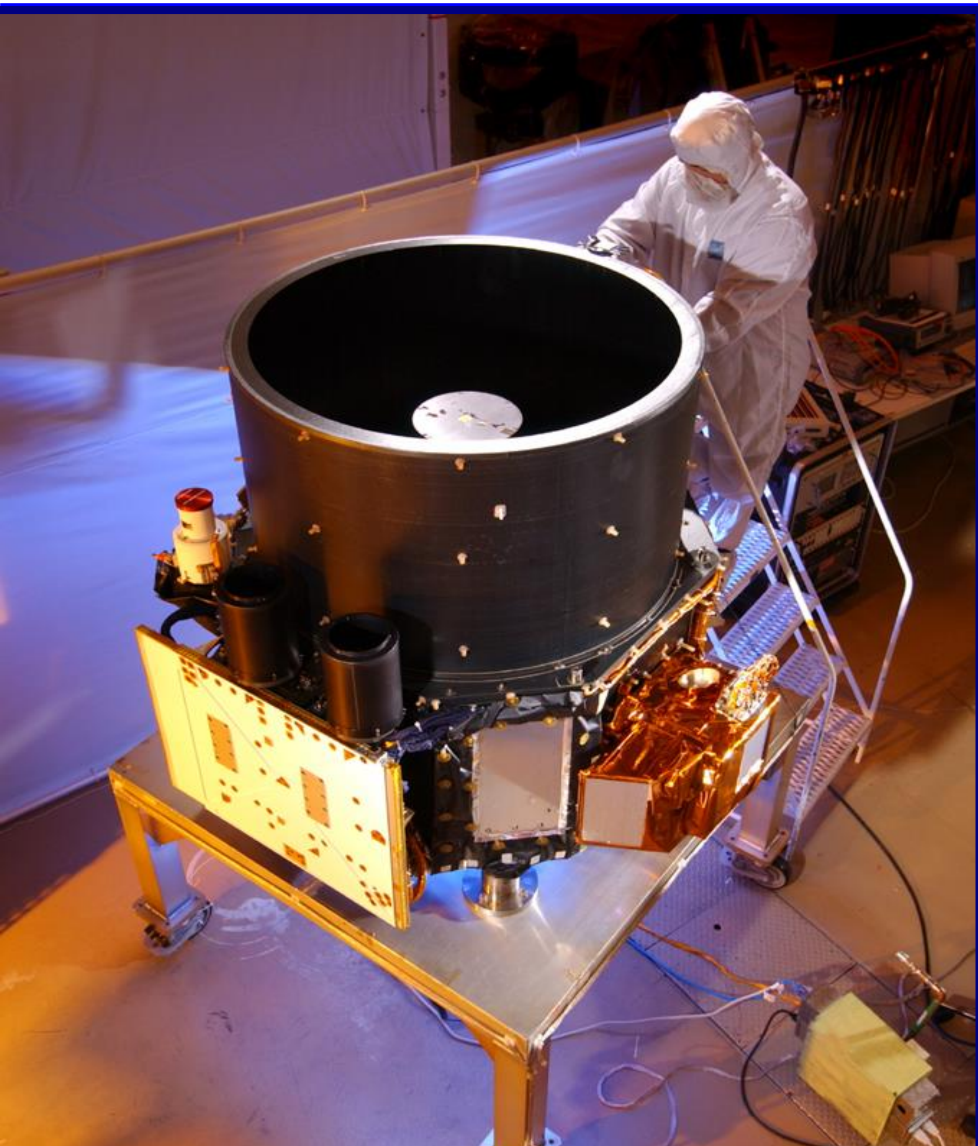
22-bit dynamic range

Active boresight adjustment

Lidar calibration:

- **$532_{\parallel}$ – normalization of molecular return**
- **$532_{\perp}$ – relative to $532_{\parallel}$ using on-board cal H/W**
- **1064 – relative to 532_{T} using cirrus backscatter**

Instrument Specifications



CALIOP

Laser	Nd: YAG, 2x110 mJ
Wavelength	532 nm, 1064 nm
Repetition rate	20.25 Hz
Receiver telescope	1.0 m diameter
Polarization	532 $\parallel$ and $\perp$
Footprint/FOV	100 m / 130 μrad
Vertical resolution	30 - 60 m
Horizontal resolution	333 m
Lin. dynamic range	22 bits

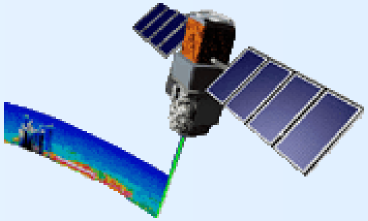
Wide-Field Camera (WFC)

Wavelength	645 nm
Spectral bandwidth	50 nm
IFOV / Swath	125 m / 61 km

Imaging Infrared Radiometer (IIR)

Wavelength	8.65, 10.6,12.05 μm
Spectral resolution	0.6-1.0 μm
IFOV / Swath	1 km / 64 km
NETD @ 210K	0.3 K
Calibration	±1 K

Lidar Spatial Resolution



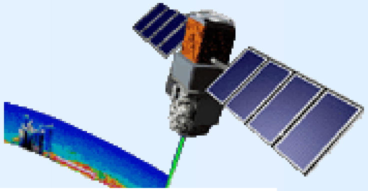
Altitude Range (km)	Horizontal Resolution (km)	532 nm Vertical Resolution (m)	1064 nm Vertical Resolution (m)
30.1 to 40.0	5.00	300	
20.2 to 30.1	1.67	180	180
8.2 to 20.2	1.00	60	60
-0.5 to 8.2	0.33	30	60
-2.0 to -0.5	0.33	300	300

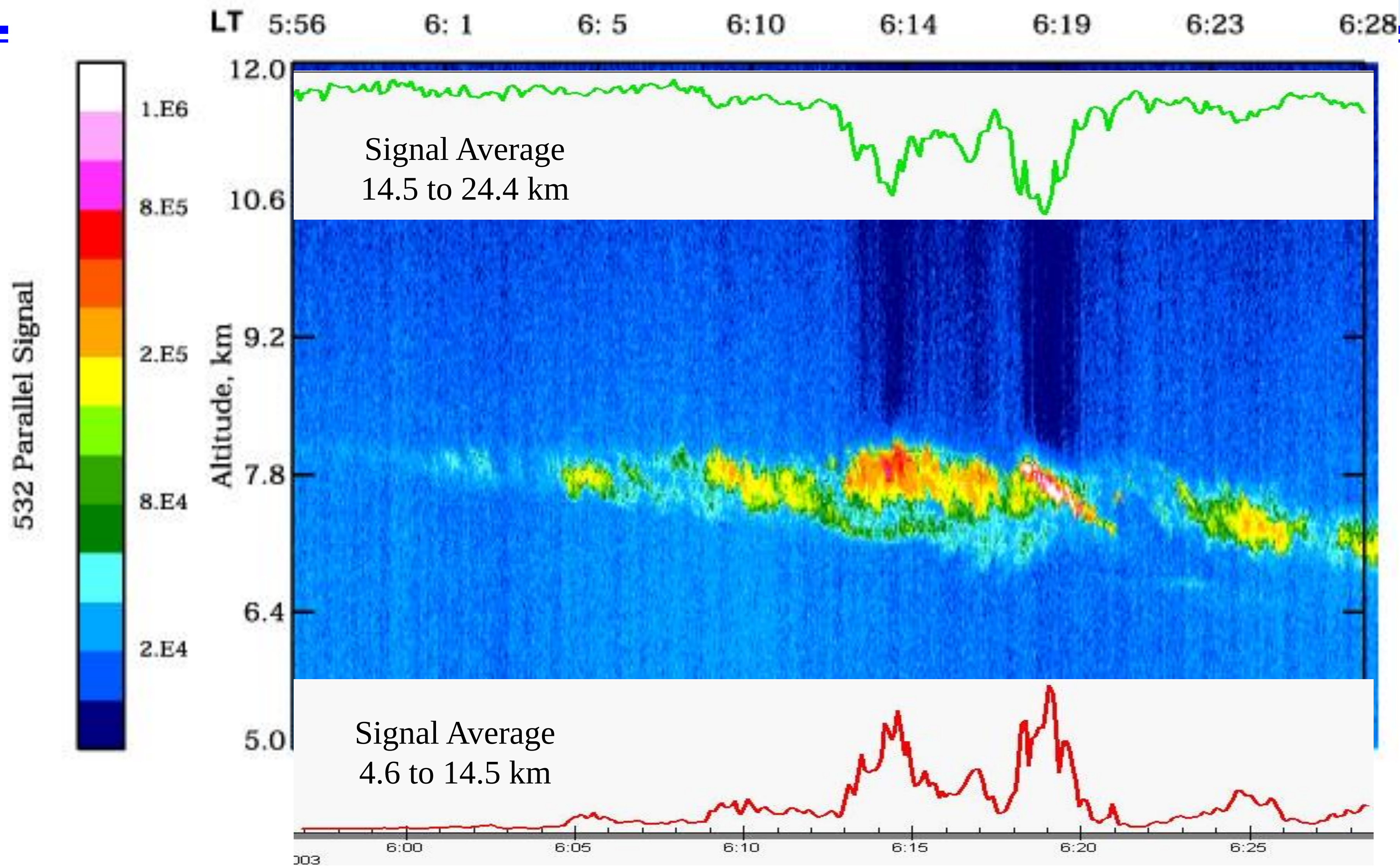
Atmospheric Test

Lidar atmospheric testing was conducted in Boulder, Colorado from Dec 7 through Dec 11, 2003.

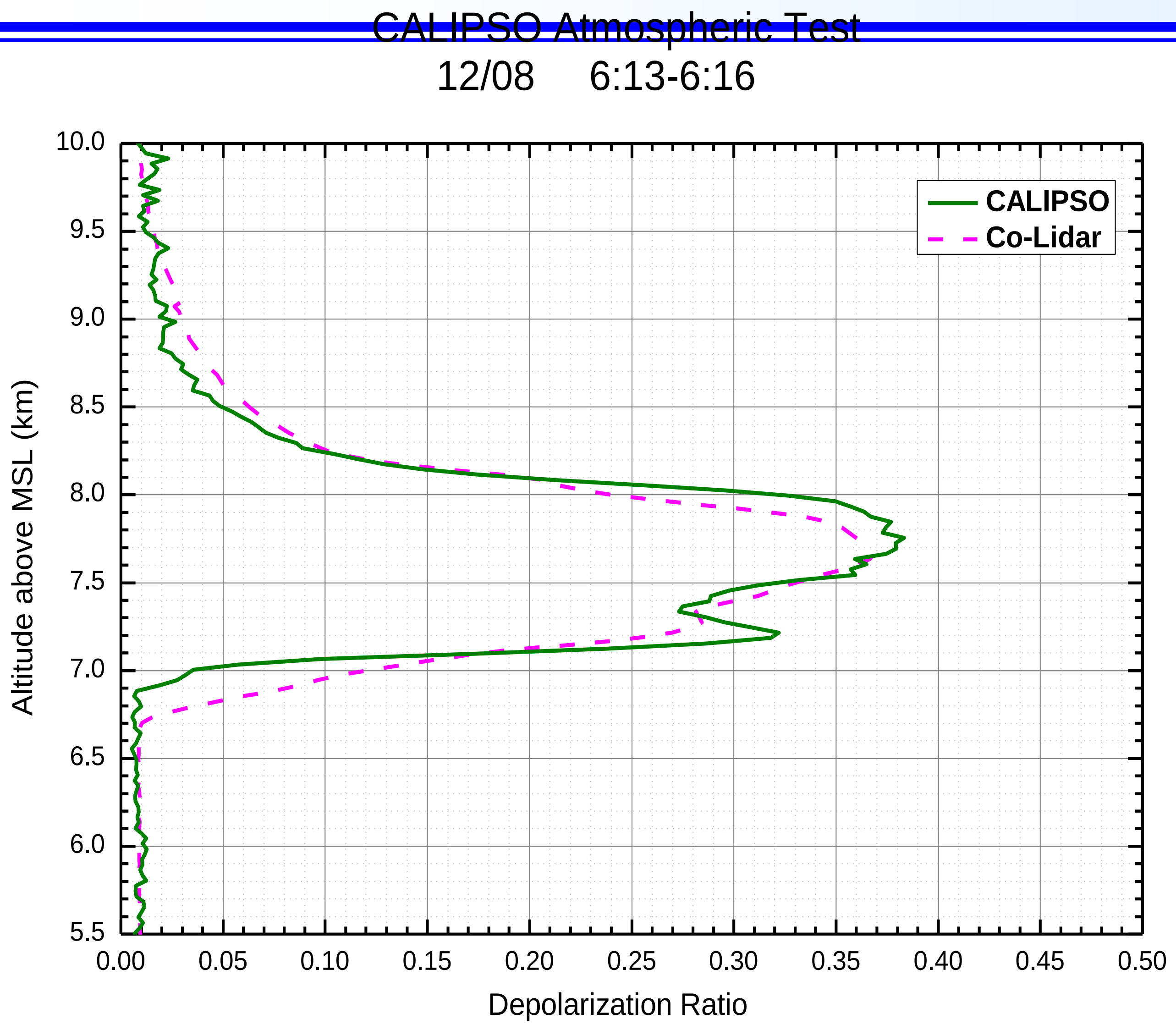
- **No problems encountered**
- **Lidar performance was outstanding on all tests.**

CALIPSO Cloud Data from 12/08/03





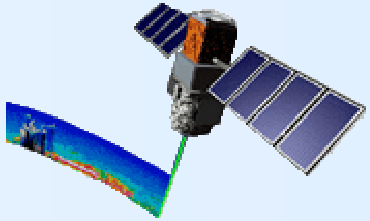
Comparison of CALIPSO and Co-Lidar Profiles

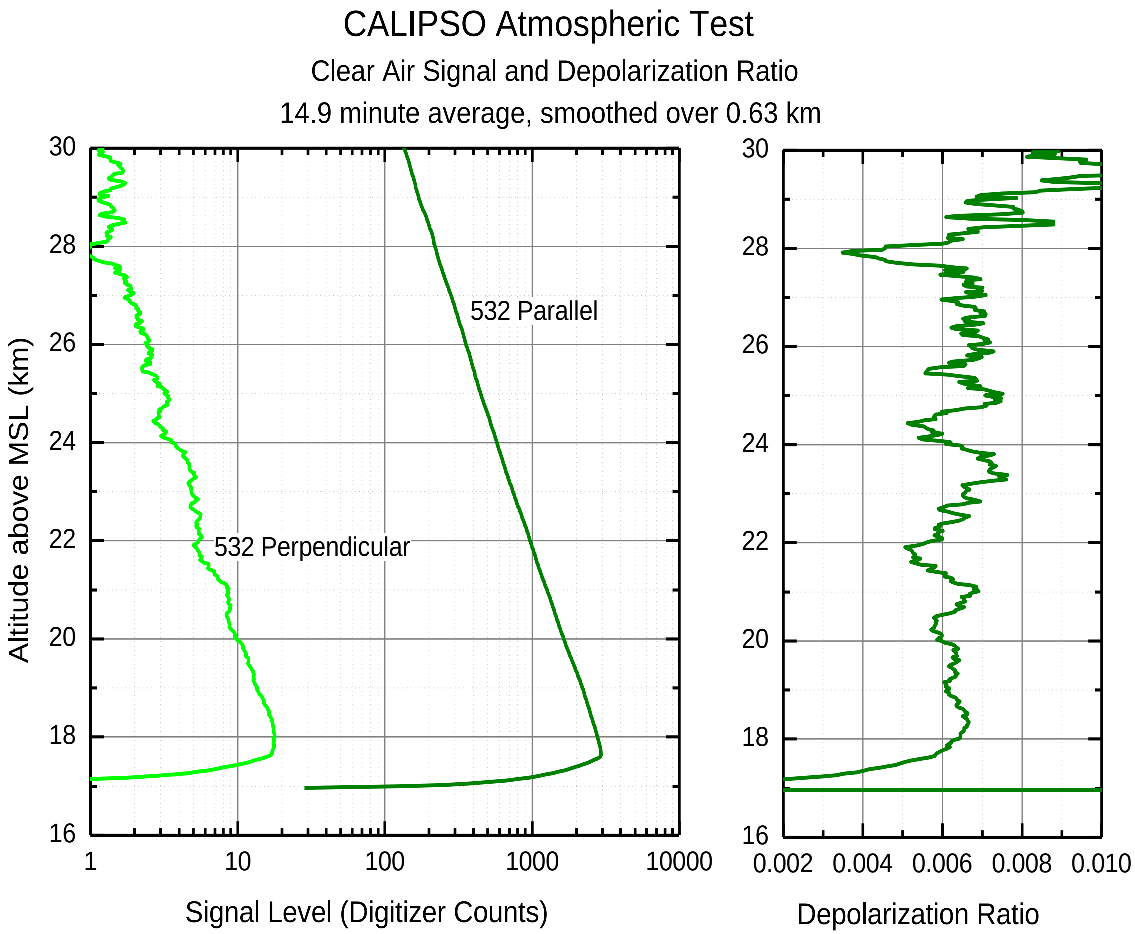


CALIPSO and the co-lidar show reasonable agreement for cloud altitudes, depolarization ratio, and profile shapes.

Further study is needed to sort out some issues with time tags and data resolution.

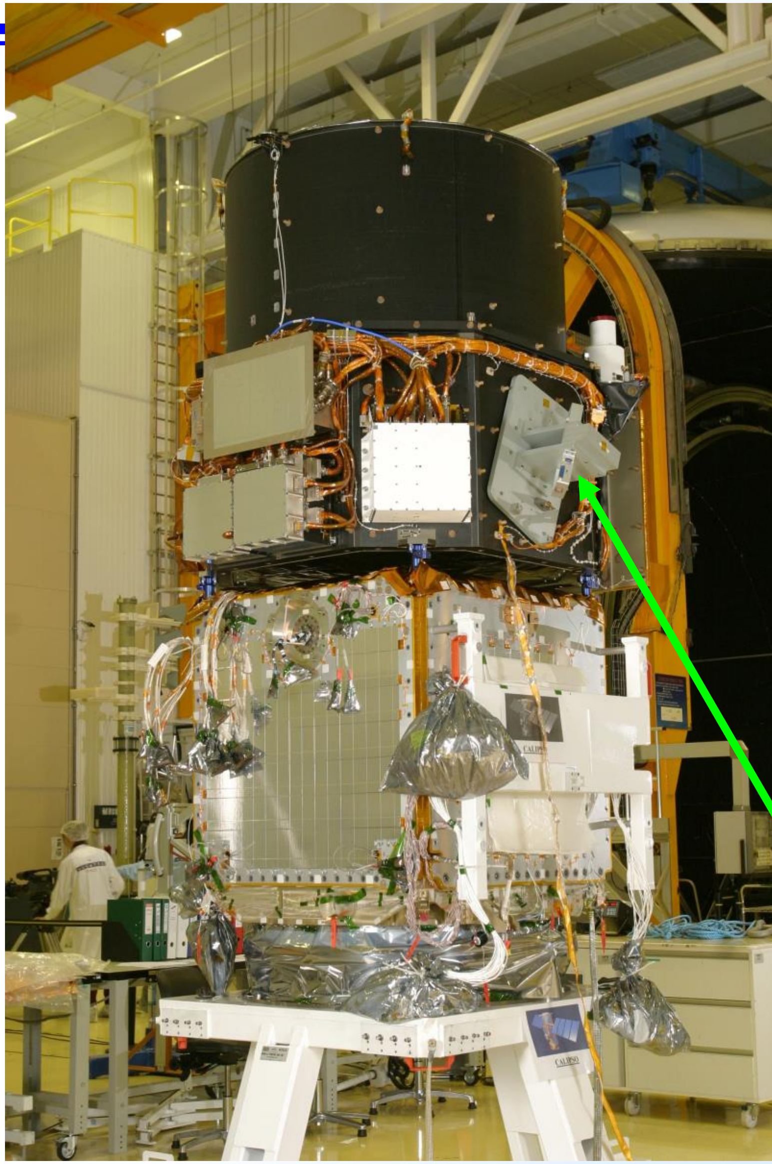
Clear Air Profile Results: Depolarization Ratio Measurement





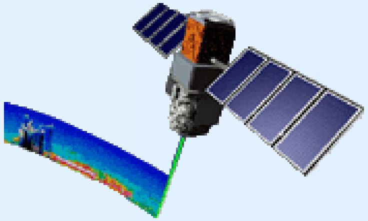
- The measured clear air depolarization ratio is < 0.7%.
- The true value should be < 0.4%.
- The difference between the measured and true value sets an upper limit on the amount of crosstalk between the polarization channels.
- The requirement is less than 1.0% crosstalk. This measurement indicates that the actual crosstalk is less than half of that.

Payload Integrated to Platform



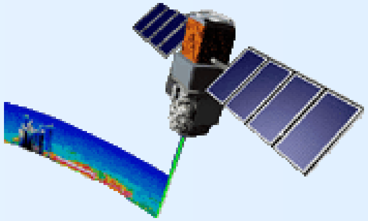
- Payload-platform mech. integration 1 Mar 2004
- Satellite Performance Verification Test completed 26 March
- Conducted E-M Compatibility (EMC) completed 9 April
- Satellite Sine-Vibe to finish today
- Satellite T/V - August

Upcoming Milestones



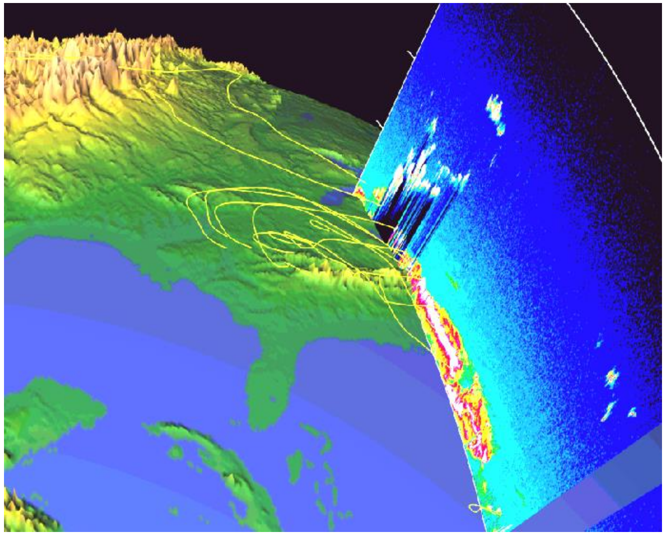
▪ ASDC/DMS Launch Readiness Review (LRR)	October 2004
▪ Flight Ops Review (FOR)	December 2004
▪ Satellite ships to VAFB	January 2005
▪ Launch	15 April 2005
▪ First lidar profiles	1 June 2005
▪ Prelim data release	1 Sept 2005

CALIPSO Mission Objectives



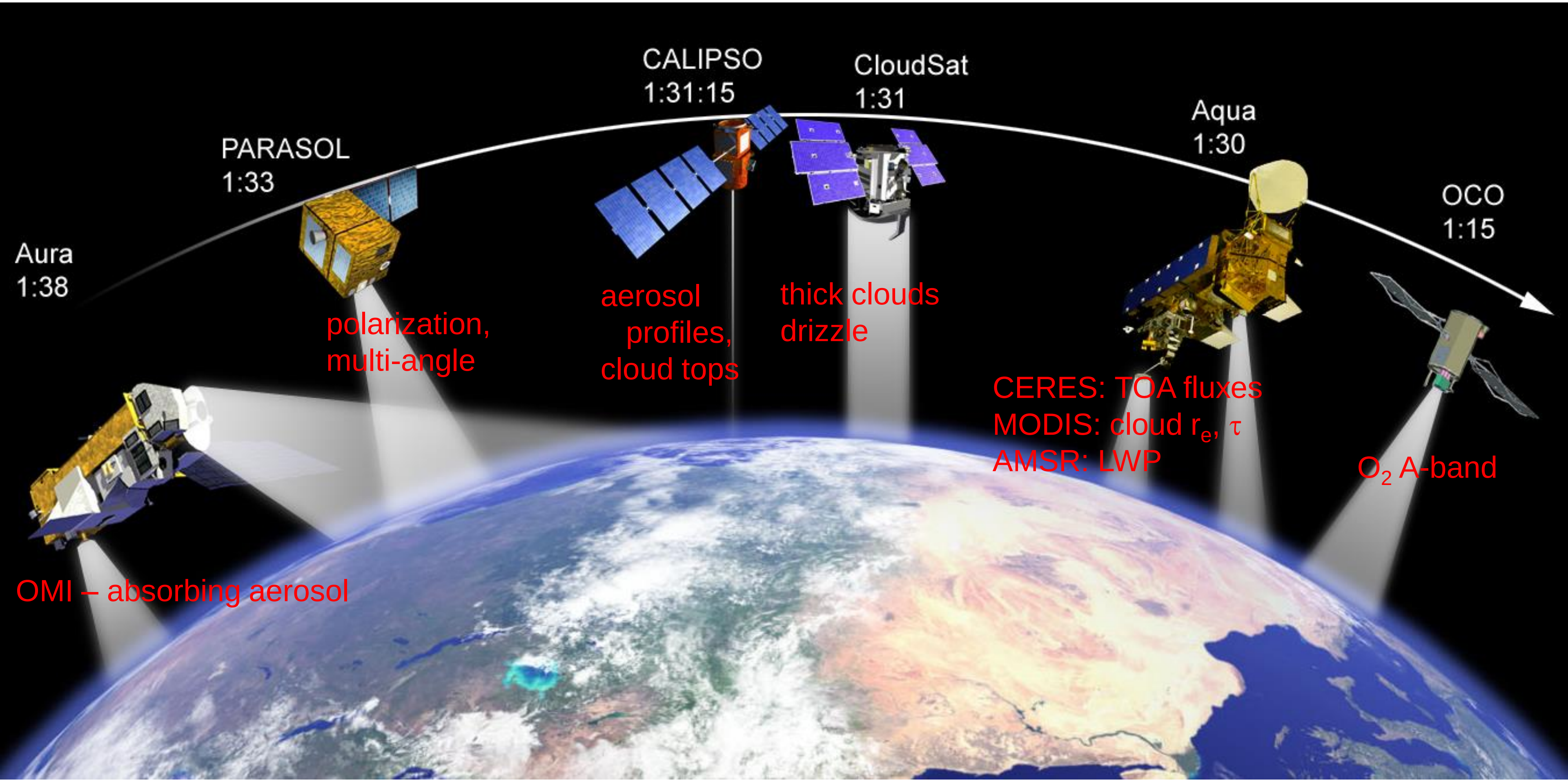
CALIPSO will fly as part of the Aqua constellation (A-train) to provide observations needed to improve:

- **Our understanding of the role of aerosols and clouds in the processes that govern climate responses and feedbacks**
  - **Direct and indirect aerosol effects**
  - **Cloud forcing and feedbacks**



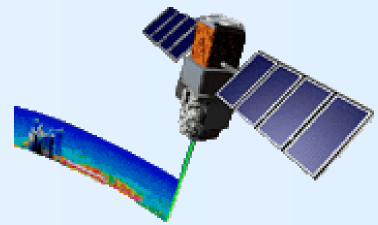
- **The representation of aerosols and clouds in models**
  - **Improved climate predictions**
  - **Improved models of atmospheric chemistry**

Synergies with the A-train



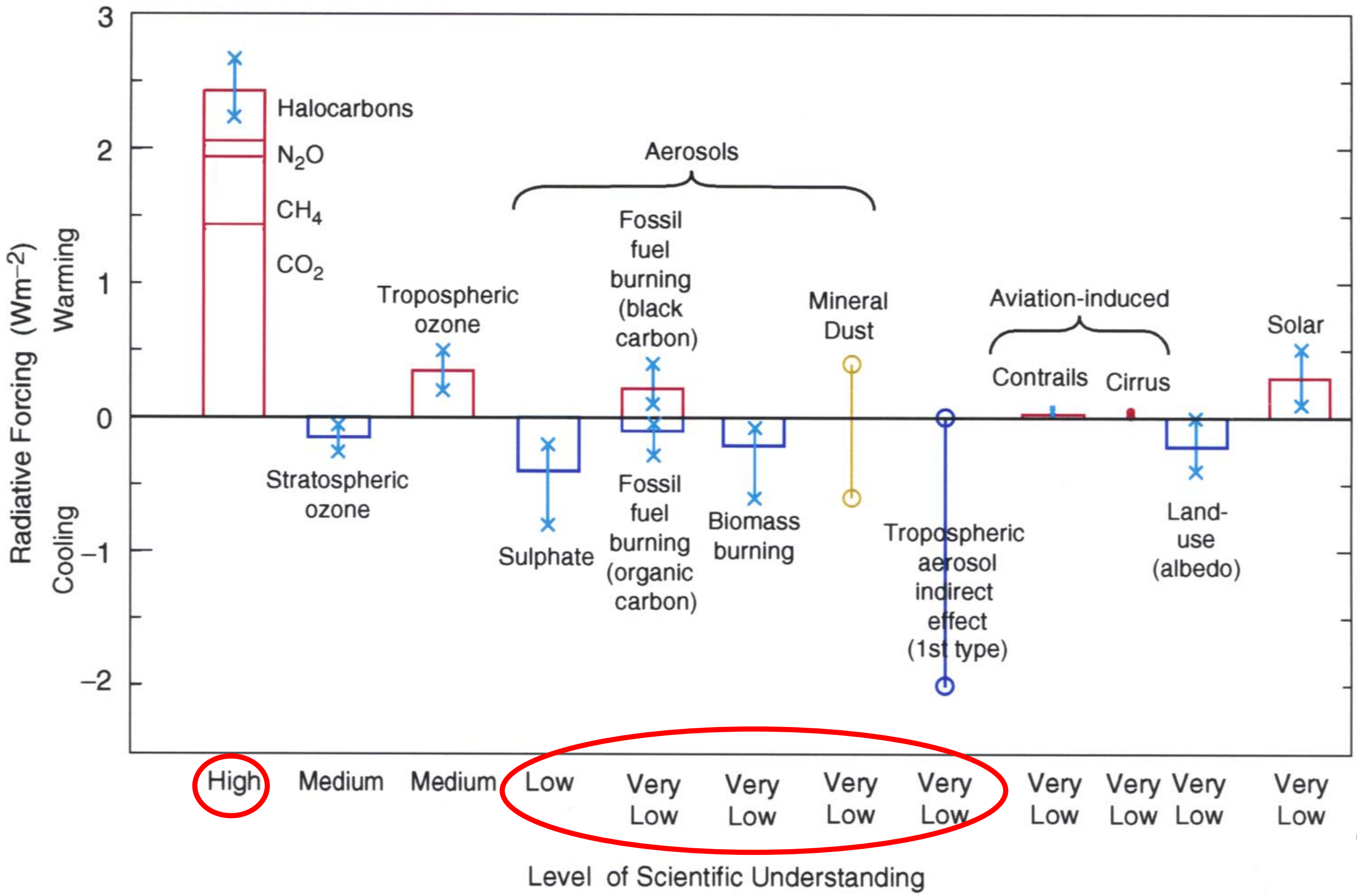
Orbit: 705 km, 98° inclination**,** 1:30 PM equator crossing

Aerosols: The Most Uncertain External Climate Forcing Agent

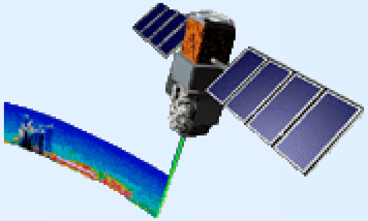


In contrast to greenhouse gases, aerosols:

- are shortlived, spatially inhomogenous, interact strongly with clouds
- composition highly variable, heterogen. chemistry poorly understood

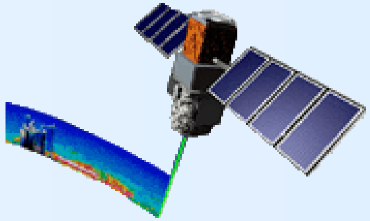


(IPCC, 2001)



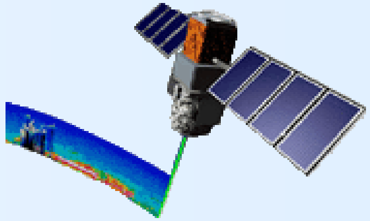
Objective for CALIPSO Beyond Climate

- Application to design and subsequent operations of future DIAL and Doppler wind lidars (DWL)
- Analysis & Improvement of current CTWs
- Application to Radiometric Sounders and NWP



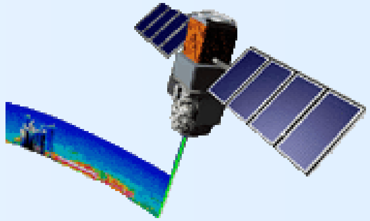
CALIPSO Influences on DWL

- CFLOS probabilities by height in atmosphere; by synoptic situation; by wind shear classification.
- Probabilities of contiguous CFLOSs for shot integrating lidars
- Nature of multiple cloud layer impacts on lidar data utility
- General global distribution of aerosols (355– 2000nm); vertical, horizontal, hemispherical, etc.
- Need CFLOS and backscatter statistics for evaluating the realism of Nature Runs used in NCEP and NASA OSSEs



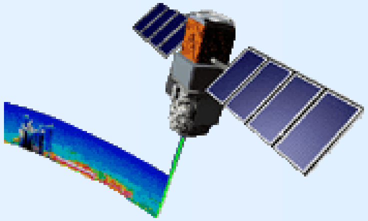
CALIPSO Influence on CTWs

- Height Assignment Validation
  - Extend/Collaborate with John Reagan, others
- Impact Assessment of Improved Height Assignment on NWP
  - Need a warm body equipped with a sharp mind



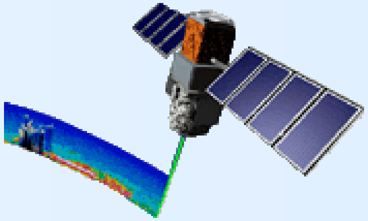
CALIPSO Influence on Conventional Sounders & NWP

- AIRS, MODIS
  - Compare/Validate Products – Cloud Cleared Radiances
  - Problems with CCRs in lowest 1-2 km, require external QA
  - CALIPSO to benefit from external data (AIRS/AMSU) @ 20 km
- Results Applicable to Subsequent Sensors
  - IASI, CrIS, VIIRS, GOES/ABI, etc.



Aerosol backscatter

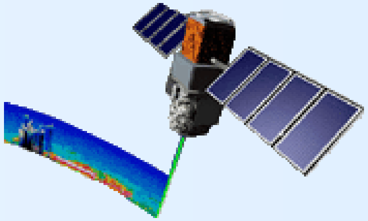
- DWLs at 2, 1.06 and .355 microns
- Can use models to estimate backscatter at wavelengths near CALIPSO’s
- Interest in nature of elevated layers; thickness, relationship to wind shear, variability in height over individual feature
- Dynamic range of Beta within entire tropospheric column.

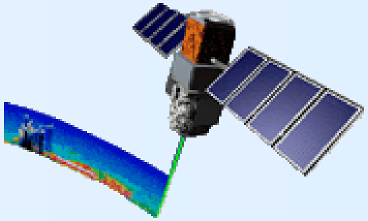


Summary

- CALIPSO promises to provide a data set critical for design trade studies of future space-based lidars
- CALIPSO will provide data to increase impact of current satellite sensors for NWP
  – May refine requirements for DWL
- DWL community should look forward to a successful CALIPSO mission that lowers the risk (and thus $$) for follow-on active optical remote sensing from space.

Back-up Slides Follow

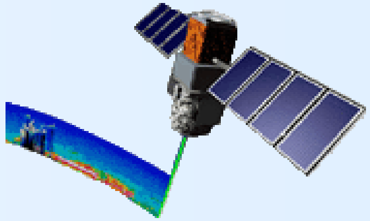




Background

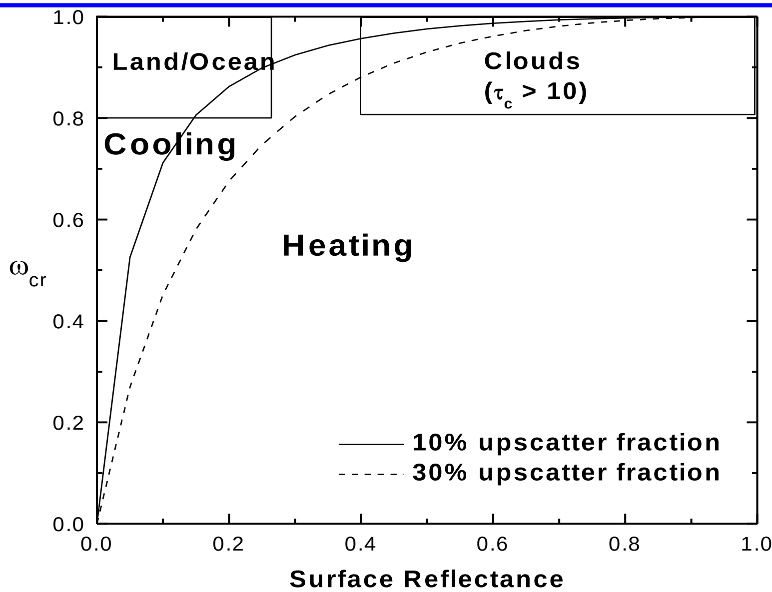
- LITE provided early insight into cloud vertical distributions and CFLOS statistics
- SLA provided very limited, but useful CFLOS statistics
- ICESat promises to expand on the LOS statistics and estimates of global aerosol backscatter distributions.

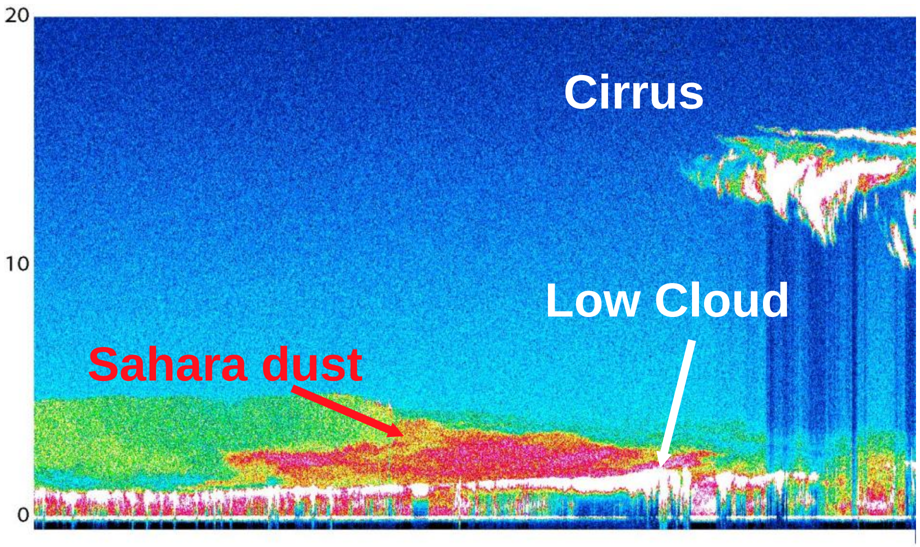
The Vertical: CALIPSO Aerosol



Aerosol Direct Radiative Forcing

- CALIPSO aerosol profiles
  - aerosol lifetime dependent on height
  - radiative effects depend on underlying reflectance
  - observe aerosol above cloud, below thin cirrus
- A-train: CALIPSO + MODIS + CERES
  - improved characterization of direct forcing

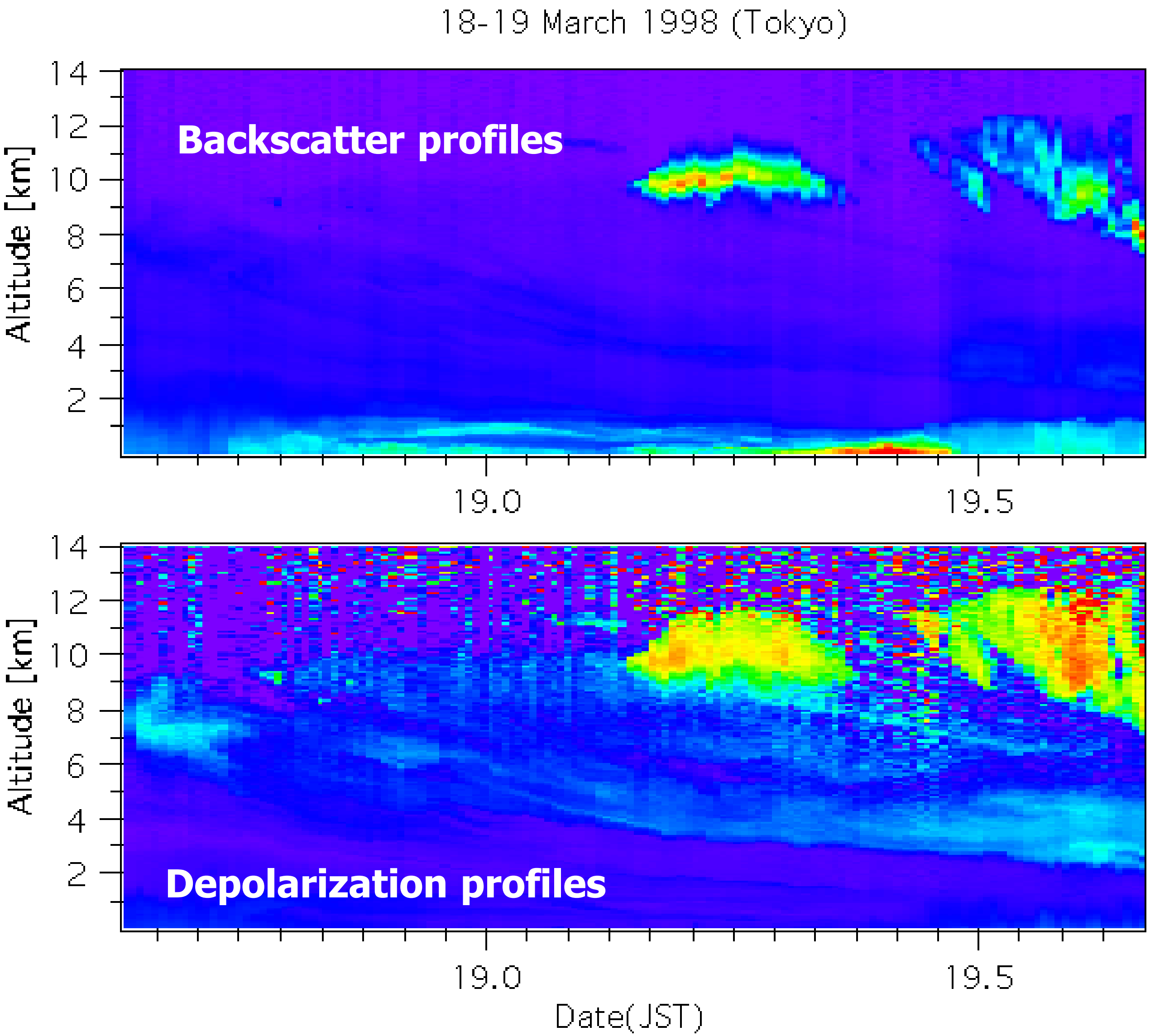




Aerosol Indirect Radiative Forcing

- CALIPSO cloud and aerosol profiles
  - unique ability to determine if cloud and aerosol are in the same layer.
- A-train: add MODIS + CERES
  - cloud microphysics, optics, radiation
- A-train: add AMSR, Cloudsat radar
  - adds LWP plus drizzle.

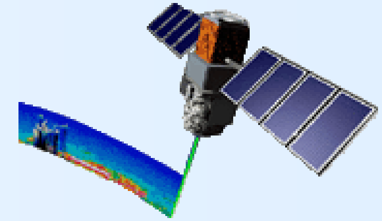
Depolarization Observations of Asian Dust



Depolarization profiles provide information on aerosol type and aid in discrimination of aerosol and cloud

Figure courtesy of T. Murayama

The Vertical:
CALIPSO/Cloudsat Cloud Layering



LW Surface Radiative Fluxes

- Vertical distribution of multilayered clouds
- Polar clouds: coverage, height

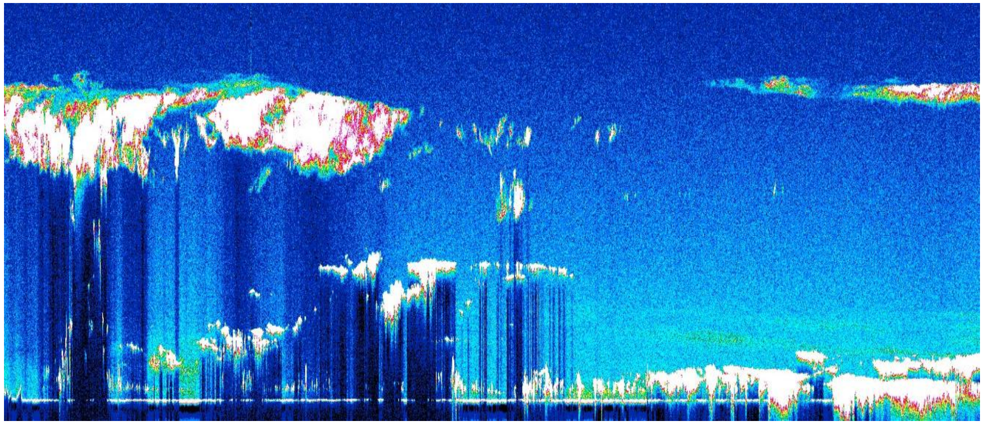
LW & SW heating/cooling rates

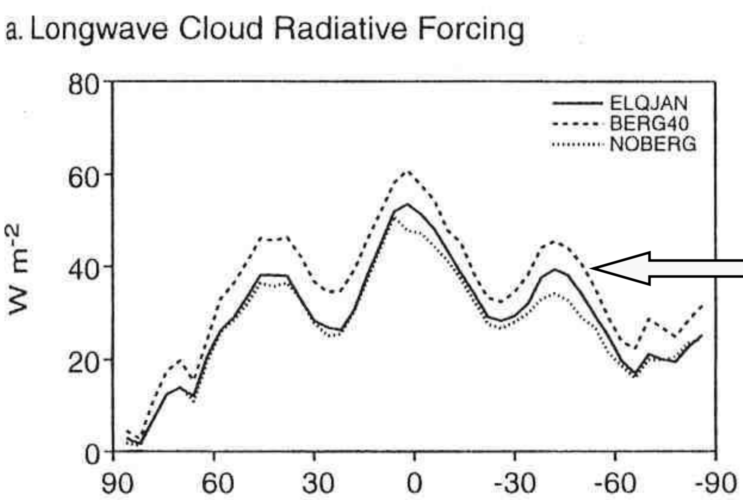
- multilayer cloud structure and thickness

CALIPSO

- 80% penetration to top of boundary layer

- **A-train add CloudSat radar**
  - adds profiles of deep convective clouds



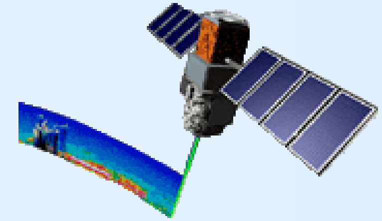


(Fowler and Randall, 1996: J. Clim. 9, 561)

LW Cloud Radiative Forcing

- The threshold temperature dividing mixed-phase and ice clouds is not well known
- Ice/water partitioning is an important modulator of the climate sensitivity in climate models
- Unique CALIPSO observations
  - improved ice/water phase, vertically resolved
  - IWP for thin cloud, Cloudsat for moderate/thick
  - IR particle size retrievals constrained by lidar cloud height and depolarization

Combined lidar/radar sensing of cloud

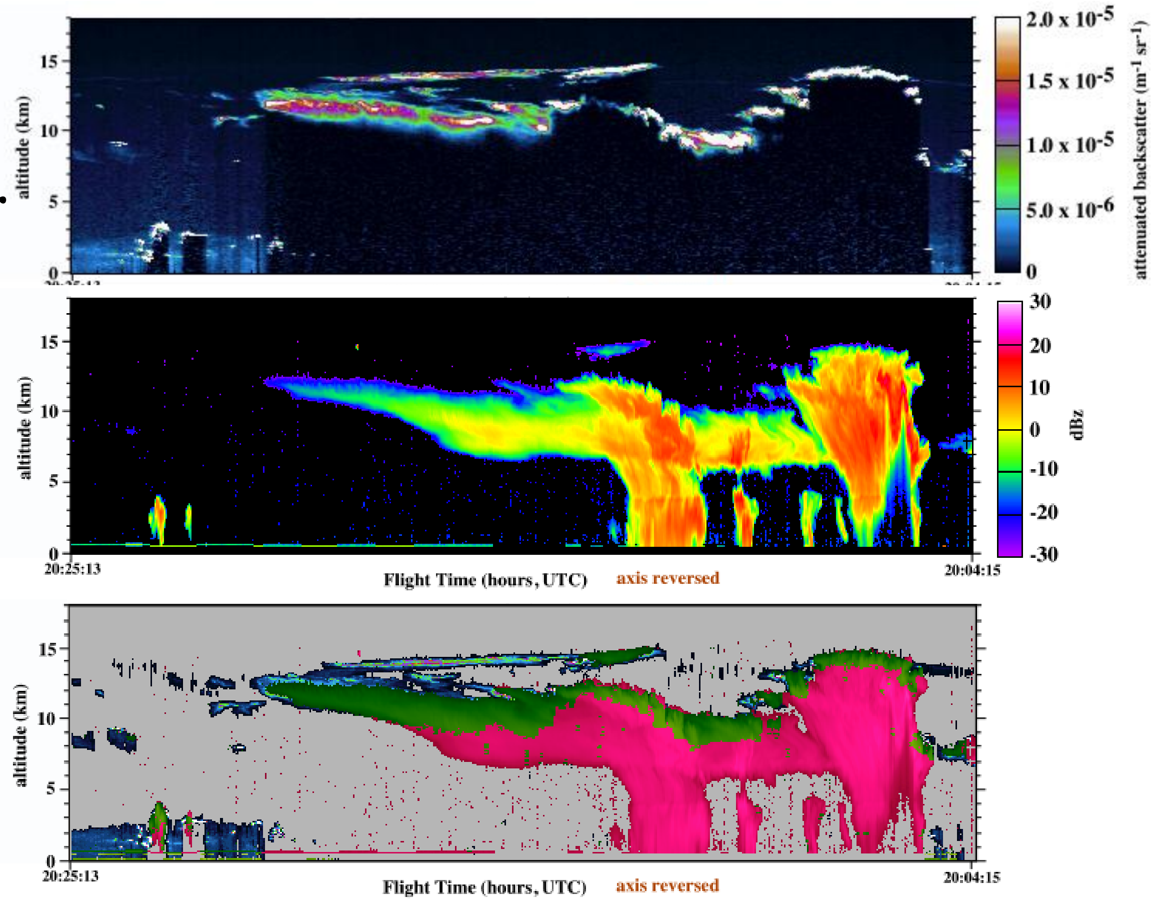


CRYSTAL-FACE,
23 July 2003

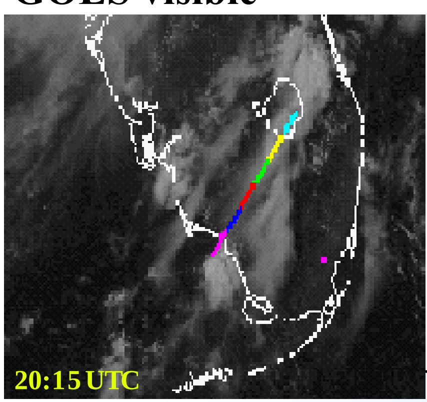
CPL lidar backscatter

CRS radar reflectivity

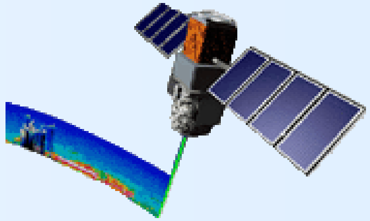
CPL+CRS composite



GOES visible

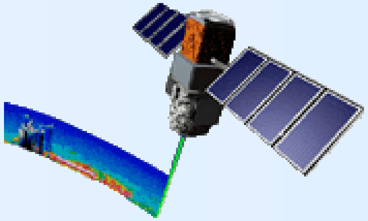


Lidar Data Products



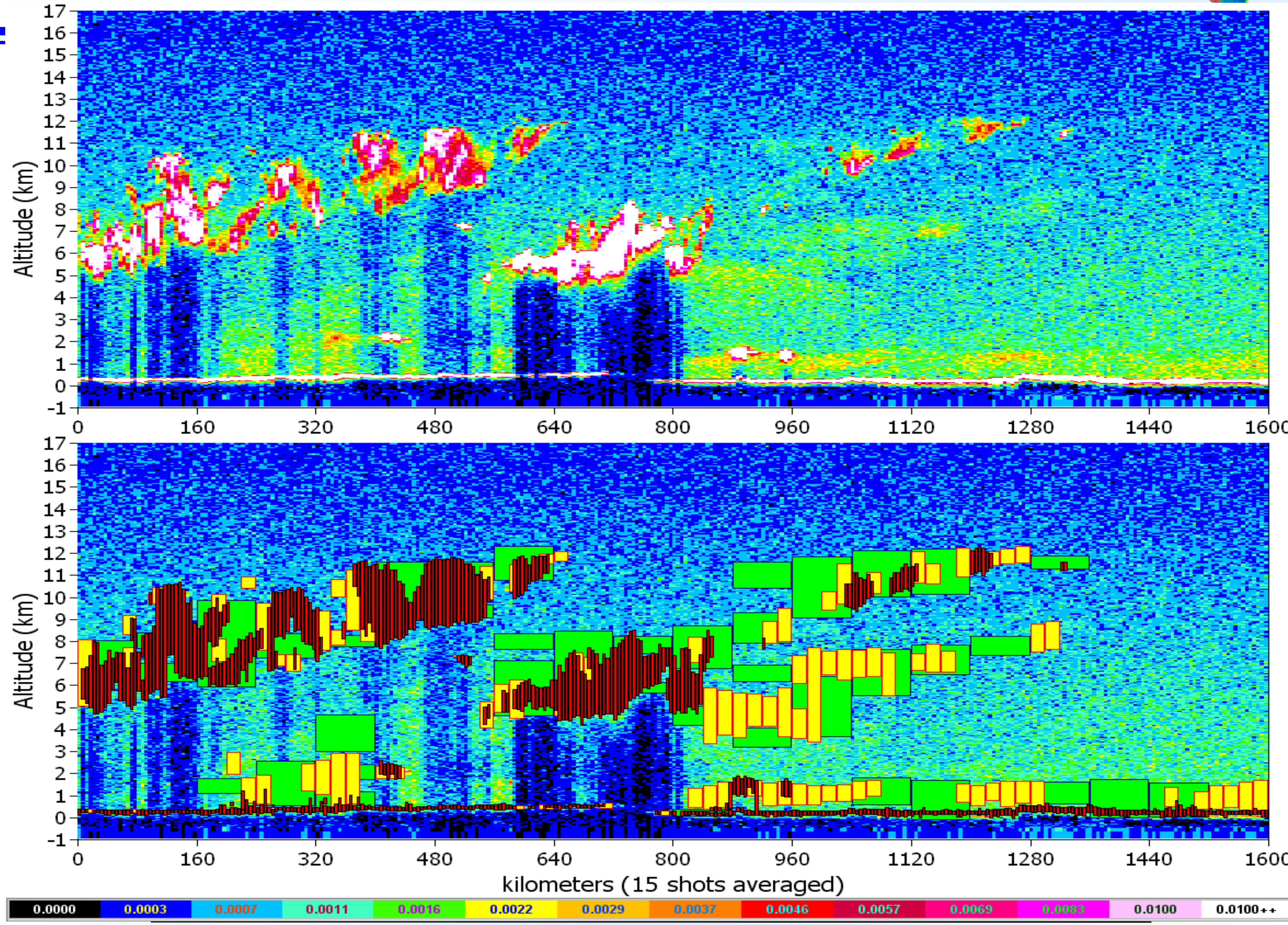
Data Product	Product Name	Primary Parameters	Maximum Altitude	Resolution	
				vertical	horizontal
DP 1.1	Level 1B Profiles	$532_{\perp+\parallel}$, $532_{\perp}$, 1064 attenuated backscatter	40 km	Full Resolution	
DP 2.1A	Cloud and Aerosol Layer Product	Cloud: base and top height, optical depth, I/W phase, IWP Aerosol: base and top height, optical depth, avg depolarization and color ratio, aerosol type	20 km 30 km	30 m 30 m	1/3, 1, 5 km 5 km
DP 2.1B	Aerosol Profile Product	532/1064 nm backscatter, extinction, depolarization	30 km	120 m	40 km
DP 2.1C	Cloud Profile Product	532 nm backscatter, extinction, depolarization, IWC	20 km	60 m	5 km
DP 2.1D	Vertical Feature Mask	cloud mask, ice/water phase aerosol mask, type	20 km	Full Resolution	

Measurement Capabilities

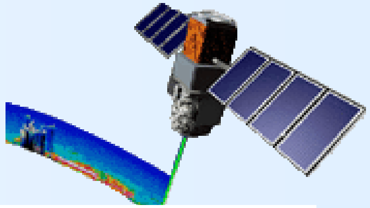


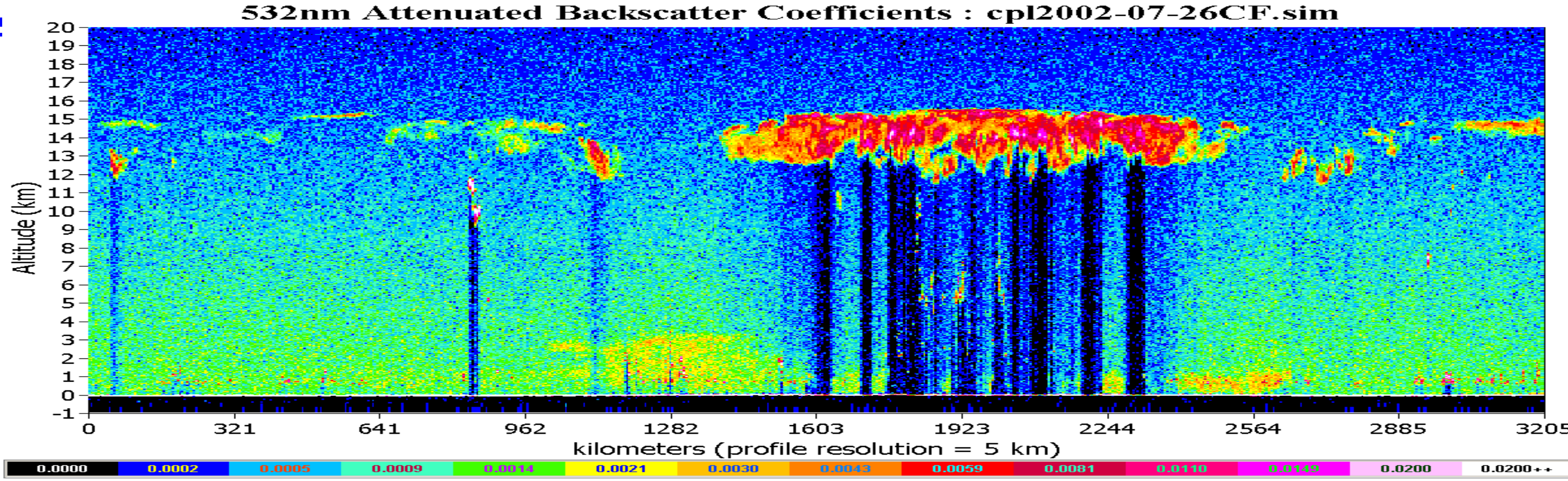
Data Product	Measurement Capabilities and Uncertainties	Representative Spatial Resolution	
		Night Horizontal x Vertical	Day Horizontal x Vertical
Aerosol layer top and base height	$\beta_{min} = 2.5 \times 10^{-4}\ km^{-1}\ sr^{-1}$ (τ = 0.005 for a 500 m thick layer)	20 km x 120 m	50 km x 120 m
Thin cloud top and base height	$\beta_{min} = 1 \times 10^{-3}\ km^{-1}\ sr^{-1}$ (τ = 0.005 for a 250 m thick layer)	1 km x 60 m	4 km x 60 m
Thick cloud base height	Layer $\tau < 5$	4 km x 60 m	50 km x 60 m
PBL cloud structure	$\beta_{min} = 1.6 \times 10^{-2}\ km^{-1}\ sr^{-1}$	333 m x 30 m	333 m x 30 m
Aerosol τ (Resolutions for case of $\tau = 0.1$)	$\frac{\partial\tau}{\tau} \leq$ 40% (total error) (includes 30% error in S)	8 km horizontal	20 km horizontal
Aerosol $\sigma(z)$	$\frac{\partial\sigma}{\sigma} \leq$ 30% (random error only)	3.5 km x 120 m	6 km x 120 m
Cirrus τ, σ (z)	Within a factor of 2 for $\tau < 5$	15 km horizontal	NA
Ice/water phase	Layer by layer	16 km x 60 m or 4 km x 240 m	16 km x 60 m or 4 km x 240 m

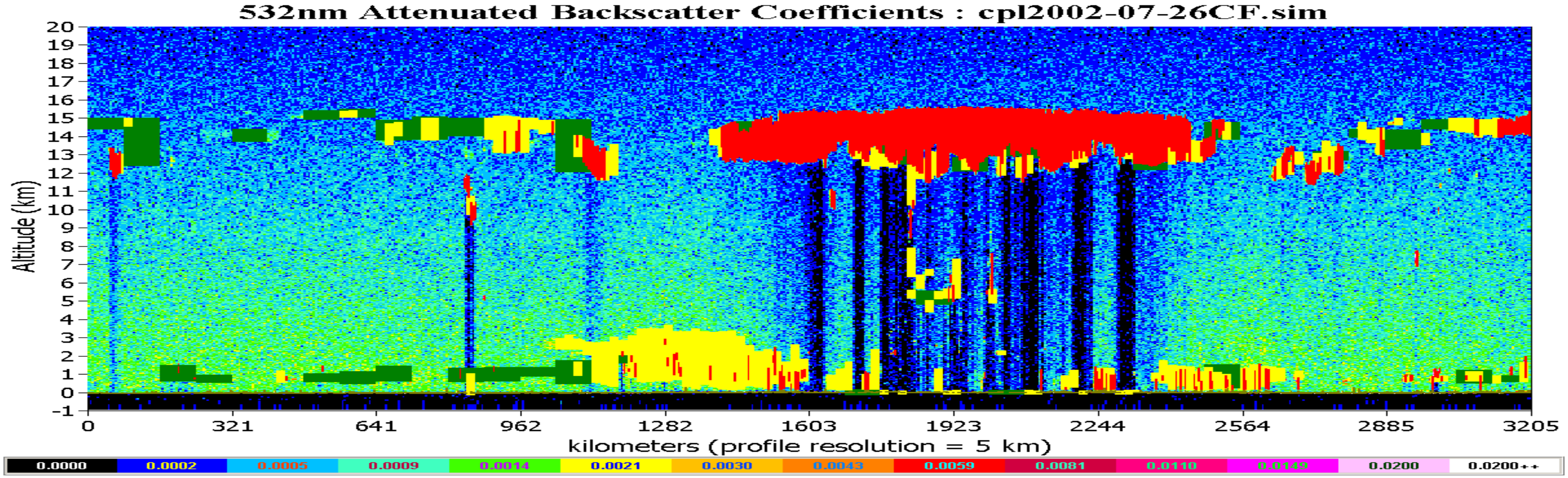
Layer Detection Simulation



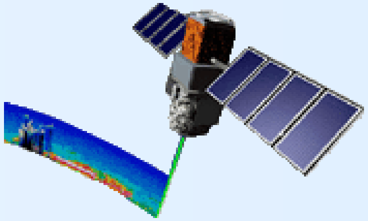
Layer Detection
CALIPSO data simulated from X-F CPL

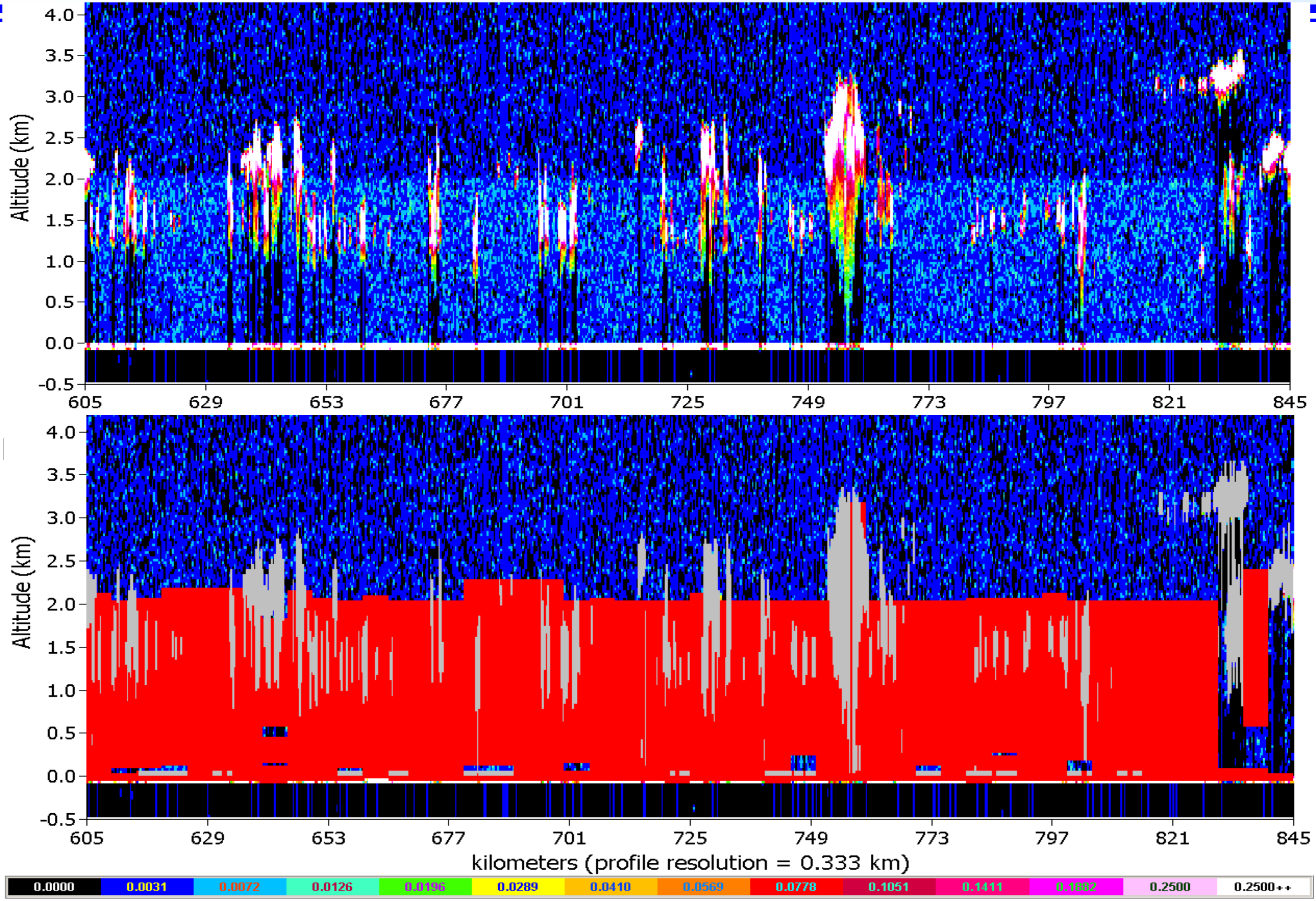


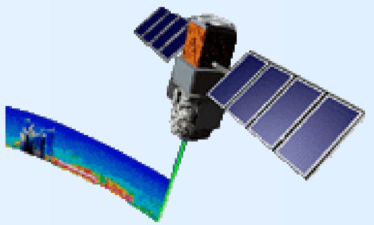




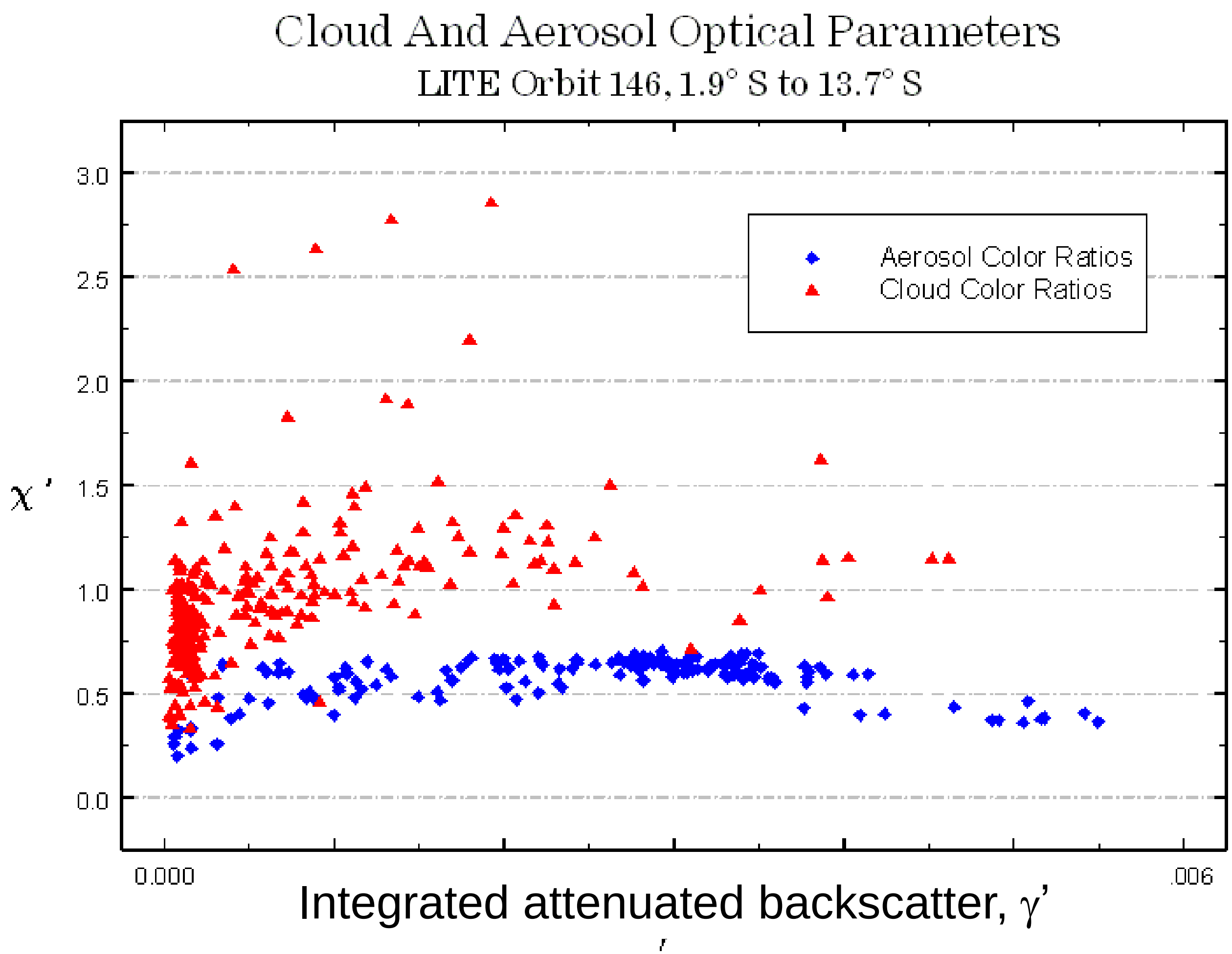
Boundary Layer Cloud Clearing







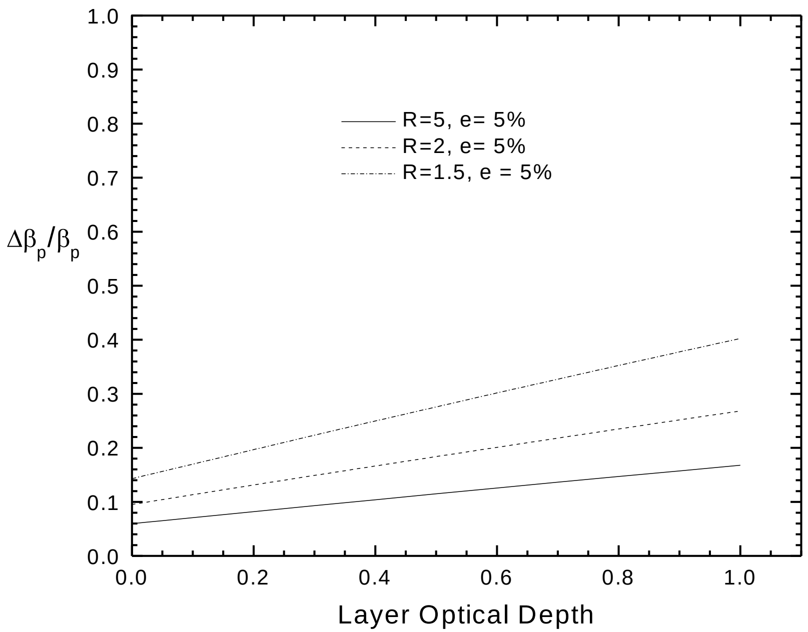
Color ratios improve cloud/aerosol separation



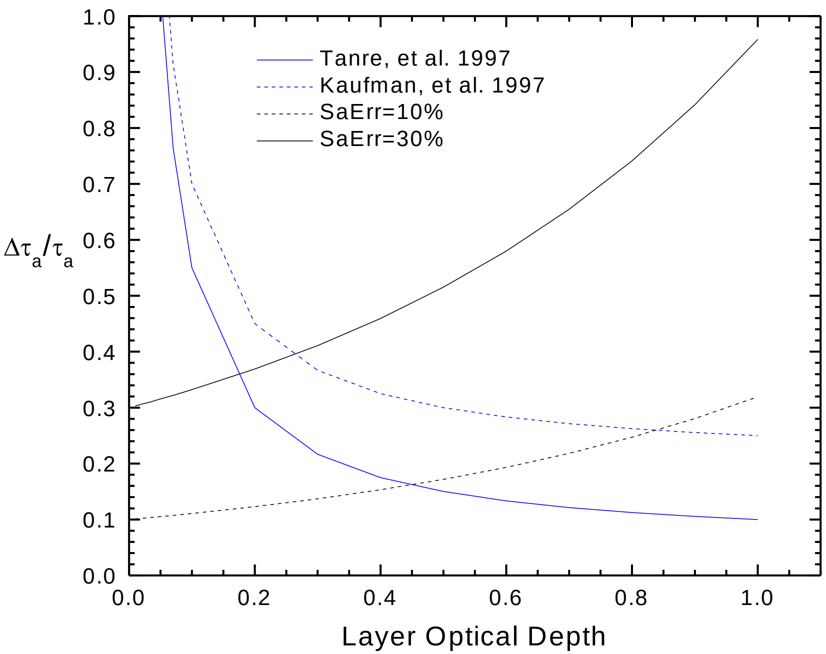
Aerosol Retrievals: MODIS vs. CALIPSO

- Uncertainties in τ_a are due to S_a (mostly) and calibration (slightly)
- lidar excels at low optical depth: $\tau < 0.2$
  - complements passive capabilities

Impact of calibration error



Impact of error in S_a



MODIS/CALIOP comparison: Cloud Opt Depth